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A major focus of our current DARPA/AFOSR contract is the development of photonic devices appropriate to integrated optical circuits. Success in this area requires a significant effort in the area of modeling and simulation of optical wave propagation. The focus of this AASERT was to develop computer-aided design and modeling software for photonic integrated circuits. This effort built on software previously developed in our group for optical waveguide simulation using the beam propagation method. In this AASERT program we have developed a broadly applicable tool for device simulation which includes the ability to handle arbitrary device structures in 2D and 3D, along with state-of-the-art numerical algorithms dealing with all possible physical phenomena of interest. A graphical user interface enables researchers and engineers to rapidly use the tool to solve problems, without being an expert in numerical methods and programming. In this report, we outline the technical achievements of this work.

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ABSTRACT

A major focus of our current DARPA/AFOSR contract is the development of photonic devices appropriate to integrated optical circuits. Success in this area requires a significant effort in the area of modeling and simulation of optical wave propagation. The focus of this AASERT was to develop computer-aided design and modeling software for photonic integrated circuits. This effort built on software previously developed in our group for optical waveguide simulation using the beam propagation method. In this AASERT program we have developed a broadly applicable tool for device simulation which includes the ability to handle arbitrary device structures in 2D and 3D, along with state-of-the-art numerical algorithms dealing with all possible physical phenomena of interest. A graphical user interface enables researchers and engineers to rapidly use the tool to solve problems, without being an expert in numerical methods and programming. In this report, we outline the technical achievements of this work.

1. STATEMENT OF THE PROBLEM STUDIED

A major focus of our current DARPA/AFOSR contract is the development of photonic devices appropriate to integrated optical circuits. Success in this area requires a significant effort in the area of modeling and simulation of optical wave propagation.

The focus of this AASERT was to develop computer-aided design and modeling software for photonic integrated circuits. This effort built on software previously developed in our group for optical waveguide simulation using the beam propagation method.[1]

In this AASERT program we intended to develop a broadly applicable tool for device simulation which would include the following features:

1) Ability to handle arbitrary device structures in 2D and 3D;

2) State-of-the-art numerical algorithms dealing with all possible physical phenomena of interest;

3) A graphical user interface enabling researchers and engineers to rapidly use the tool to solve problems, without being an expert in numerical methods and programming.

In this report, we outline the technical achievements of this work. In summary, the above objectives have been successfully met, as evidenced by the fact that the software we have developed has been licensed to a commercial software company, RSoft, Inc., and the product, *BeamPROP*, is the leading software of its type in the U.S. market.

2. SUMMARY OF RESULTS

In this section, we outline the key accomplishments made under this AASERT.

In the first task, the previously existing program[1], which was written in FORTRAN, was hand-translated into C++. This accomplished two goals central to the success of the project. First, it allows the use of modern class libraries for GUI development, which simplifies programming and increases portability. Second, it provides a highly-portable base of code which allows the simulation to be run on PCs, workstations, and supercomputers if necessary.

In the second major task, a modern, object-oriented graphical interface was added to the program, using a portable class library that spans DOS, Windows, OS/2, and

UNIX/Motif. The interface includes a complete CAD system which allows optical circuits to be laid out using the mouse. A palette of basic waveguide slopes including straight, curved, y-branch, and s-bend waveguides is available. Standard CAD operatives exist to allow components to be moved, sized, flipped, and duplicated. Specialized programming features of the software allow the user to design a circuit based on user-defined variables, such as a branch angle, and then modify the entire circuit by simply changing the value of the variable. This allows parametric design studies to be made conveniently and efficiently.

The above newly-developed CAD software was then seamlessly linked with the translated simulation software to produce the total package. After laying out a circuit using the CAD tools of the main program, a simulation is initiated by simply clicking on a button. A dialog presents the user with a choice of numerical parameters to be used in the simulation, and the program provides intelligently-chosen default parameters based on the characteristics of the circuit being simulated. The actual simulation incorporates real-time display and analysis of results.

The third major area of development consisted of incorporating algorithms to address all key physical phenomena of interest. The first was the inclusion of techniques to address propagation in circuits with large angles or refractive index differences. The software implements a multi-step Padé based algorithm as described by Hadley.[2]

In addition, we have complete a large body of original work on analysis and application of wide-angle beam propagation techniques to large-area PICs. This has been published in the *Journal of Lightwave Technology*.[3] This work has determined the key issues in being able to model large-area PICs, and demonstrates that accurate simulation can be performed on such devices. Design rules are provided to guide the modeler as to the relative merits of different algorithms and techniques.

Next, the simulation software was expanded to incorporate polarization by developing and implementing a new full-vector bream propagation method. This method follows work done by W.P. Huang,[4] but provides a faster and more robust algorithm.

In addition, the ability to handle anisotropic media has been included. Recently, the program has been expanded to incorporate nonlinear optical effects in the simulation, and developments on bi-directional simulation are underway.

In summary, we have developed a complete CAD system for designing arbitrarily complex photonic integrated circuits which employs all state-of-the-art beam propagation techniques for simulation. As an example, Fig. 1 shows the design of an arrayed-waveguide grating router, which has become the component of choice for large WDM systems. As noted above, this software has been licensed and is available as a commercial product called *BeamPROP*, through RSoft, Inc., Montrose, NY.

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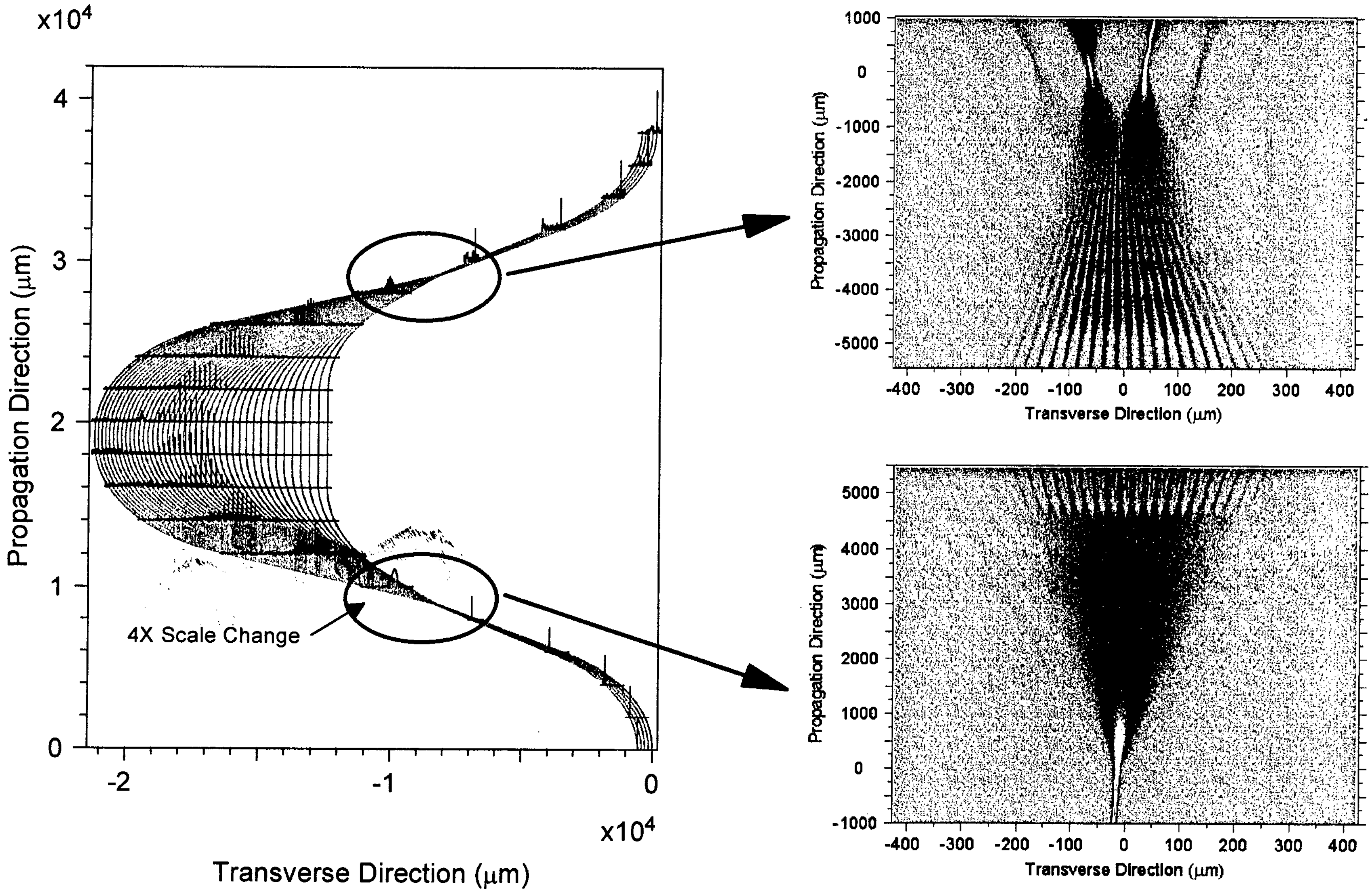

Figure 1. Computer-Aided Design of Arrayed-Waveguide Grating Router for WDM

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4. TECHNICAL REPORTS PUBLISHED

None

5. INVENTIONS

None

6. PERSONNEL SUPPORTED AND DEGREES EARNED

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